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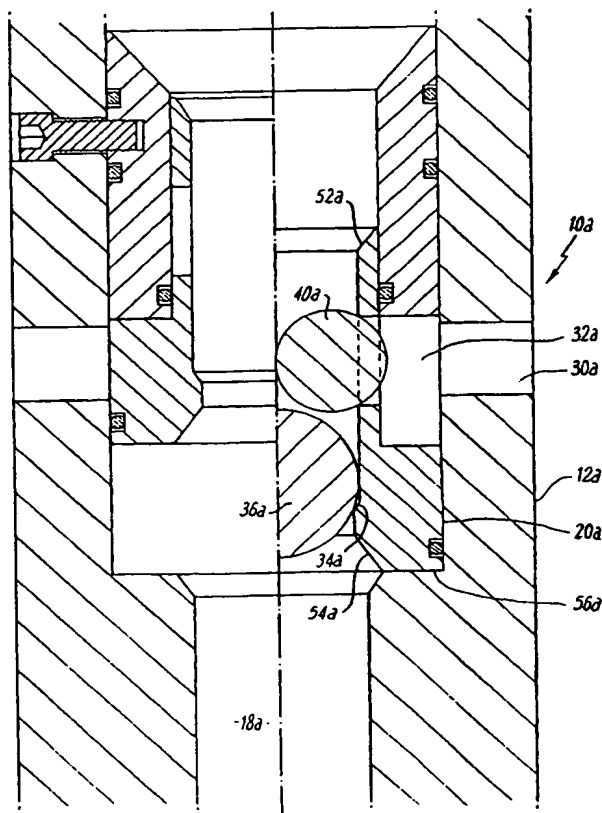
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(54) Title: DOWNHOLE CIRCULATION VALVE OPERATED BY DROPPING BALLS



(57) Abstract: A downhole tool (10) for selectively circulating fluid in a borehole is disclosed. The tool operates via the use of a combination of deformable drop balls (36) and smaller hard drop balls (40). In use a deformable drop ball (36) moves a sleeve (20) exposing a radial port (30,32) to provide fluid circulation radially from the tool. The smaller drop ball (40) can then obstruct the radial port (32,30) and by the increased pressure the deformable drop ball (36) is extruded through the tool. The resulting pressure differential as the drop ball (36) moves causes the sleeve (20) to rise, releasing the smaller drop (40) ball and closing the radial port (32,30). The process can be repeated to selectively circulate fluid through the tool.

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## DOWNHOLE CIRCULATION VALVE OPERATED BY DROPPING BALLS

1 Downhole Tool

2

3 This invention relates to apparatus and method for  
4 circulating fluid in a borehole.

5

6 It is known that this operation can be achieved by  
7 employing a downhole tool connected on a drill string.

8 The tool includes means for circulating fluid through the  
9 length of the drill string and also redirecting the fluid  
10 at higher flow rates out of the drill string onto the  
11 walls of the borehole.

12

13 Such tools are of at least two generic types. One type  
14 of tool is a weight-set tool. Such a tool comprises a  
15 tubular assembly connected to the drill string and  
16 includes a general axial fluid outlet, a generally  
17 transversed fluid outlet and an obturating member which  
18 is moveable between a first position and a second  
19 position at which the transverse fluid outlet is open.  
20 The obturating member is moved relative to the tubular  
21 assembly by extending or collapsing the tool, the latter  
22 movement occurring by causing a shoulder coupled to the  
23 obturating member to engage with a formation in the

1 borehole. Such tools have the disadvantage that they  
2 require contact to a formation within the borehole, thus  
3 a ledge or formation must exist within the borehole.  
4

5 A second type of circulation tool utilises the well known  
6 practice of dropping spherical balls or darts down the  
7 drill string to open or close valves, thereby alternating  
8 the circulation paths of fluid. The main disadvantage of  
9 these tools is that it is difficult to control both axial  
10 and radial fluid flow from a single spherical ball.  
11 There is also known difficulties in achieving release of  
12 the ball so that axial fluid may be established through  
13 the drill string.  
14

15 An object of the present invention is to provide an  
16 improved downhole tool for fluid circulation, which  
17 obviates or at least mitigates some of the disadvantages  
18 of the prior art.  
19

20 A further object of the present invention is to provide  
21 an improved downhole tool for fluid circulation which can  
22 be repeatably operated downhole.  
23

24 A yet further object of the present invention is to  
25 provide an improved downhole tool for fluid circulation  
26 which is operated by fluid pressure and does not require  
27 the incorporation of springs.  
28

29 According to a first aspect of the present invention  
30 there is provided a downhole tool for circulating fluid  
31 within a borehole, the tool comprising:  
32

33 a tubular assembly having an axial through passage

1 between an inlet and a first outlet, a second outlet  
2 extending generally transversely from the tubular  
3 assembly and the through passage including a lower ball  
4 retaining means;

5

6 an obturating member including an upper ball retaining  
7 means, the obturating member being moveable relative to  
8 the tubular assembly between a first position closing the  
9 second outlet and a second position at which the second  
10 outlet is open; and

11

12 first ball means being retainable within said upper and  
13 said lower ball retaining means to prevent fluid flow  
14 between the inlet and first outlet and the first ball  
15 means being deformable under increased fluid pressure to  
16 pass through said upper and said lower ball retaining  
17 means.

18

19 Preferably the tool further includes second ball means  
20 wherein the second ball means is of a size which when  
21 located in the second outlet prevents fluid flow  
22 therethrough.

23

24 Preferably the ball means is a spherical drop ball. More  
25 preferably the first ball means has a larger diameter  
26 than the second ball means.

27

28 Preferably also the first ball means is made from an  
29 extrudable material, such as a plastic or phenolic  
30 material.

31

32 Preferably the second ball means is made from a hard  
33 material, such as steel or the like.

1  
2 Preferably the upper and lower ball retaining means is a  
3 generally circular shoulder or ledge. Thus the first ball  
4 means seats on the ball retaining means preventing fluid  
5 flow between the inlet and first outlet. When fluid  
6 pressure increases the first ball means is extruded by  
7 deforming through the ball retaining means.

8  
9 Preferably the obturating member is a sleeve. More  
10 preferably the sleeve includes a radial port.

11  
12 Additionally the sleeve may be coupled to a collet. The  
13 collet allows the sleeve to be releasably engaged to the  
14 tubular assembly. The collet also allows the radial port  
15 to remain aligned with the second outlet by preventing  
16 the sleeve from turning within the tubular assembly.

17  
18 Preferably the tool further includes catching means for  
19 catching the ball means once they have passed through the  
20 ball retaining means. Such a catching means allows the  
21 balls to be collected and returned from the well once the  
22 tool has finished its operations.

23  
24 According to a further aspect of the present invention,  
25 there is provided a method of circulating fluid in a  
26 borehole comprising the steps of:

- 27
- 28 (a) connecting a downhole tool, according to the first  
29 aspect of the present invention, in a drill string  
30 suspended in the borehole;
  - 31
  - 32 (b) establishing fluid flow through the axial through  
33 passage of the tool;

- 1
- 2 (c) releasing the first ball means into the axial  
3 through passage to seat in the upper ball retaining  
4 means thereby obstructing the axial fluid flow  
5 through the tool;  
6
- 7 (d) moving the obturating member by the increase of  
8 fluid pressure against the first ball means to  
9 locate the radial port with the second outlet  
10 thereby allowing fluid flow through the second  
11 outlet;  
12
- 13 (e) releasing the second ball means from the surface,  
14 such that the second ball means locates in the  
15 radial port thereby obstructing the fluid flow  
16 through the second outlet;  
17
- 18 (f) forcing the first ball means passed the upper  
19 ball retaining means by the increase in pressure so  
20 as to locate the first ball means in the lower ball  
21 retaining means, the first ball means falling a  
22 distance comparatively short enough to ensure  
23 sufficient pressure to move the obturating member  
24 back up the tubular assembly thereby closing the  
25 radial port and releasing the second ball means; and  
26
- 27 (g) allowing the fluid pressure to increase to a  
28 sufficient pressure to cause the first ball means to  
29 pass through the lower ball retaining means and the  
30 second ball means to follow therethrough and allow  
31 axial fluid flow to be re-established.  
32
- 33 Preferably the method also includes catching the ball

1 means in a catching means at the bottom of the tool.

2

3 An advantage of the method of the present invention is  
4 that the steps may be repeated any number of times to  
5 provide circulation of fluid through the tool.

6

7 In order to provide a better understanding of the  
8 invention, embodiments will now be described, by way of  
9 example only, with reference to the following Figures, in  
10 which:

11

12 Figures 1 through 4 are sequential part cross-sectional  
13 views through a downhole tool according to a first  
14 embodiment of the present invention; and

15

16 Figure 5 is a part cross-sectional view through a  
17 downhole tool according to a second embodiment of the  
18 present invention.

19

20 Referring initially to Figure 1, there is shown a top  
21 section of a downhole tool, termed a circulating tool and  
22 generally referred to by reference numeral 10, according  
23 to a first embodiment of the present invention. The  
24 circulating tool 10 comprises a tubular assembly 12  
25 having a first end 14 including a screw thread connection  
26 16 to connect the circulating tool 10 to a drill string  
27 (not shown). Tubular assembly 12 includes an axial  
28 through passage 18. When located in a borehole the tool  
29 section shown in Figure 1 is closest to the surface.

30

31 Reference is now made to Figure 2 of the drawings which  
32 depicts a further section of the circulating tool 10 in a  
33 downward direction from the surface. Inside tubular



1 assembly 12 is located the obturating member 20 in the  
2 form of a sleeve 20. Sleeve 20 is coupled to a collet 22  
3 which is slidable against an inner sleeve 24 of the  
4 tubular assembly 12. Inner sleeve 24 is held in place by  
5 a retaining pin or grub screw 26. Collet 22 can move  
6 longitudinally against inner sleeve 24, and can  
7 releasably engage in circular recess 28. Sleeve 20, inner  
8 sleeve 24 and the outer wall of the tubular assembly 12  
9 are each provided with sealing means in the form of o-  
10 rings to prevent the ingress of fluid therebetween.

11  
12 Reference is now made to figure 3 of the drawings which  
13 depicts a further section of the circulation tool 10. In  
14 this embodiment sleeve 20 includes port 32 which when  
15 sleeve 20 is in an open position aligns with a radial  
16 port 30 in the tubular assembly 12. In this open position  
17 sleeve 20 is located against shoulder 38 of tubular  
18 assembly 12. A first spherical ball 36 is located against  
19 a shoulder 34 of the sleeve 20 which retains the ball 36  
20 as fluid flows via ports 30 and 32. A second spherical  
21 ball 40 is shown located in port 30 thereby closing the  
22 fluid flow radially from the tool 10. It will be  
23 apparent that when collet 22 is located in recess 28 the  
24 sleeve 20 is in the closed position, obturating the  
25 outlet port 30.

26  
27 In tubular assembly 12 there is also located seat 42  
28 which is of a diameter sufficient to retain ball 36.  
29 When ball 36 is extruded through seat 42 it is caught in  
30 catcher 44 and prevented from flowing through the drill  
31 string by the peg 46. Ball 40 can pass cleanly through  
32 seats 34, 42 and will come to rest in the ball catcher 44.

33

1 Reference is now made to figure 4 of the drawings which  
2 illustrates ball catcher 44 including balls 36a,b and  
3 40a,b. It will be appreciated that the location of pin 46  
4 will determine how many balls may be retained in the ball  
5 catcher 44. The location of the balls 36a,b 40a,b does  
6 not obstruct fluid flow through axial through passage 18  
7 and out of first outlet 48. Outlet 48 includes connection  
8 means 50 in the form of a screw thread for connecting the  
9 circulation tool 10 to a further downhole drill  
10 string(not shown).

11

12 In use, tool 10 is attached in a drill string with the  
13 sleeve 20 held in the closed position which obturates  
14 outlet port 30. The sleeve 20 is held in this closed  
15 position by the location of collet 22 in recess 28.

16

17 To operate the tool 10, ball 36 is dropped down the axial  
18 through passage in the fluid flow and comes to rest  
19 against shoulder 34. Ball 36 seals against shoulder 34  
20 and blocks fluid flow through the tool 10. The fluid  
21 pressure pushes ball 36 and consequently sleeve 20 in the  
22 axial direction of fluid flow through passage 18. Sleeve  
23 20 comes to rest against shoulder 38 and radial port 32  
24 is aligned with the outlet port 30. Fluid flow is now  
25 radially from the tool via port 30. This radial flow can  
26 be of high pressure as the port 30 may be of a small  
27 diameter or be shaped as a jet (not shown).

28

29 When the radial fluid flow is required to be stopped a  
30 second ball 40 is dropped into the passage 18 at the  
31 surface. Ball 40 is carried in the fluid and forced  
32 against port 32 thereby sealing the radial port 30. Ball  
33 40 is made of steel to withstand the downhole pressure

1 exerted upon it. However, the consequential increase in  
2 fluid pressure in the passage 18 causes ball 36, which is  
3 made of a deformable plastic, to be extruded through the  
4 seat 34. Ball 36 is then forced against lower seat 42 and  
5 because the distance between the seats 34 and 42 is  
6 relatively small, i.e. approximately 6 inches for ball  
7 diameters of 2 inches and 1.75 inches and inner passage  
8 diameter of 3.75 inches, the resulting pressure  
9 differential at the base of the sleeve 20 causes the  
10 sleeve 20 to move upwards to the closed position. As the  
11 sleeve 20 moves upwards ball 40 is released into the  
12 axial fluid flow and falls through seat 34.

13

14 With radial port 30 now closed, all fluid pressure is  
15 substantially against ball 36 and the ball 36 is extruded  
16 by deforming through the seat 42 and falls into the ball  
17 catcher 44. Ball 36 is held within the ball catcher 44 by  
18 the retaining pin 46. Ball 40 falls through seat 42 and  
19 is also held within the ball catcher 44.

20

21 If radial flow is required again the above procedure may  
22 be repeated without the need for removing the tool 10  
23 from the borehole. This procedure may be repeated until  
24 the ball catcher is full whereby the tool is returned to  
25 the surface for the catcher 44 to be emptied.

26

27 Reference is now made to Figure 5 of the drawings which  
28 depicts a section of the circulation tool 10a in  
29 accordance with a second embodiment of the present  
30 invention. Like parts to those of Figures 1 to 4 have  
31 been given the same numerals but are suffixed "a". Tool  
32 10a works in an identical fashion to tool 10 except that  
33 collet 22 has been removed. In the second embodiment,

1 sleeve 20a is arranged such that surface 52 is smaller  
2 than surfaces 54 and 56 which ensures that sleeve 20a  
3 moves up to and remains in the closed position without  
4 the need of the collet 22.

5  
6 The principal advantage of the present invention is that  
7 it may be operated solely by hydraulic pressure of the  
8 fluid within the borehole, the tool requires no springs  
9 or locking/engaging means to move the obturating member.  
10 A further advantage of the present invention is that  
11 circulation of the fluid can be selectively started and  
12 stopped any of number of times and is only dependent on  
13 the available space in the ball catcher mechanism at the  
14 base of the tool is used. Thus this removes the need for  
15 shearing mechanisms found in other fluid circulating  
16 tools.

17  
18 It will be appreciated by those skilled in the art that  
19 various modifications may be made to the present  
20 invention without departing from the scope thereof. For  
21 example the ball means could equally be darts or any  
22 other shaped objects which will travel through the fluid  
23 and locate in the ball retaining means.

1    CLAIMS

2

3    1.    A downhole tool for circulating fluid within a  
4        borehole, the tool comprising:

5

6        a tubular assembly having an axial through passage  
7        between an inlet and a first outlet, a second outlet  
8        extending generally transversely from the tubular  
9        assembly and the through passage including a lower  
10       ball retaining means;

11

12       an obturating member including an upper ball  
13       retaining means, the obturating member being  
14       moveable relative to the tubular assembly between a  
15       first position closing the second outlet and a  
16       second position at which the second outlet is open;  
17       and

18

19       first ball means being retainable within said upper  
20       and said lower ball retaining means to prevent fluid  
21       flow between the inlet and first outlet and the  
22       first ball means being deformable under fluid  
23       pressure above a first pressure to pass through said  
24       upper and said lower ball retaining means.

25

26    2.    A downhole tool as claimed in Claim 1 wherein the  
27        tool further includes second ball means wherein the  
28        second ball means is of a size which when located in  
29        the second outlet prevents fluid flow therethrough.

30

31    3.    A downhole tool as claimed in Claim 1 or Claim 2  
32        wherein the ball means is a spherical drop ball.

33

- 1 4. A downhole tool as claimed in Claim 2 or Claim 3  
2 wherein the first ball means has a larger diameter  
3 than the second ball means.  
4
- 5 5. A downhole tool as claimed in any preceding Claim  
6 wherein also the first ball means is made from an  
7 extrudable material, which is deformable under a  
8 pressure above the first pressure.  
9
- 10 6. A downhole tool as claimed in any of Claims 2 to 5  
11 wherein the second ball means is made from a hard  
12 material, which is not deformable.  
13
- 14 7. A downhole tool as claimed in any preceding Claim  
15 wherein the upper and lower ball retaining means are  
16 substantially circular shoulders arranged so that  
17 the first ball means seats on the ball retaining  
18 means preventing fluid flow between the inlet and  
19 first outlet until the first pressure is reached  
20 whereupon the first ball means is extruded by  
21 deforming through the ball retaining means.  
22
- 23 8. A downhole tool as claimed in any preceding Claim  
24 wherein the obturating member is a sleeve.  
25
- 26 9. A downhole tool as claimed in Claim 8 wherein the  
27 sleeve includes a radial port.  
28
- 29 10. A downhole tool as claimed in any preceding Claim  
30 wherein the obturating member is coupled to a collet  
31 so that it is releasably engaged to the tubular  
32 assembly.  
33

1 11. A downhole tool as claimed in Claim 10 when  
2 dependent on Claim 9 wherein the radial port remains  
3 aligned with the second outlet by virtue of the  
4 collet.

5

6 12. A downhole tool as claimed in any preceding Claim  
7 wherein the tool further includes catching means for  
8 catching the ball means once they have passed  
9 through the ball retaining means.

10

11 13. A method of circulating fluid in a borehole,  
12 comprising the steps of:

13

14 (a) connecting in a drill string in a borehole, a  
15 tubular assembly including an axial through  
16 passage and a radial port;

17

18 (b) dropping a first ball into the axial through  
19 passage to rest within the axial through  
20 passage below the radial port thereby causing  
21 fluid in the through passage to be directed  
22 through the radial port;

23

24 (c) dropping a second ball into the axial through  
25 passage to rest in the radial port and prevent  
26 fluid flow through the tool; and

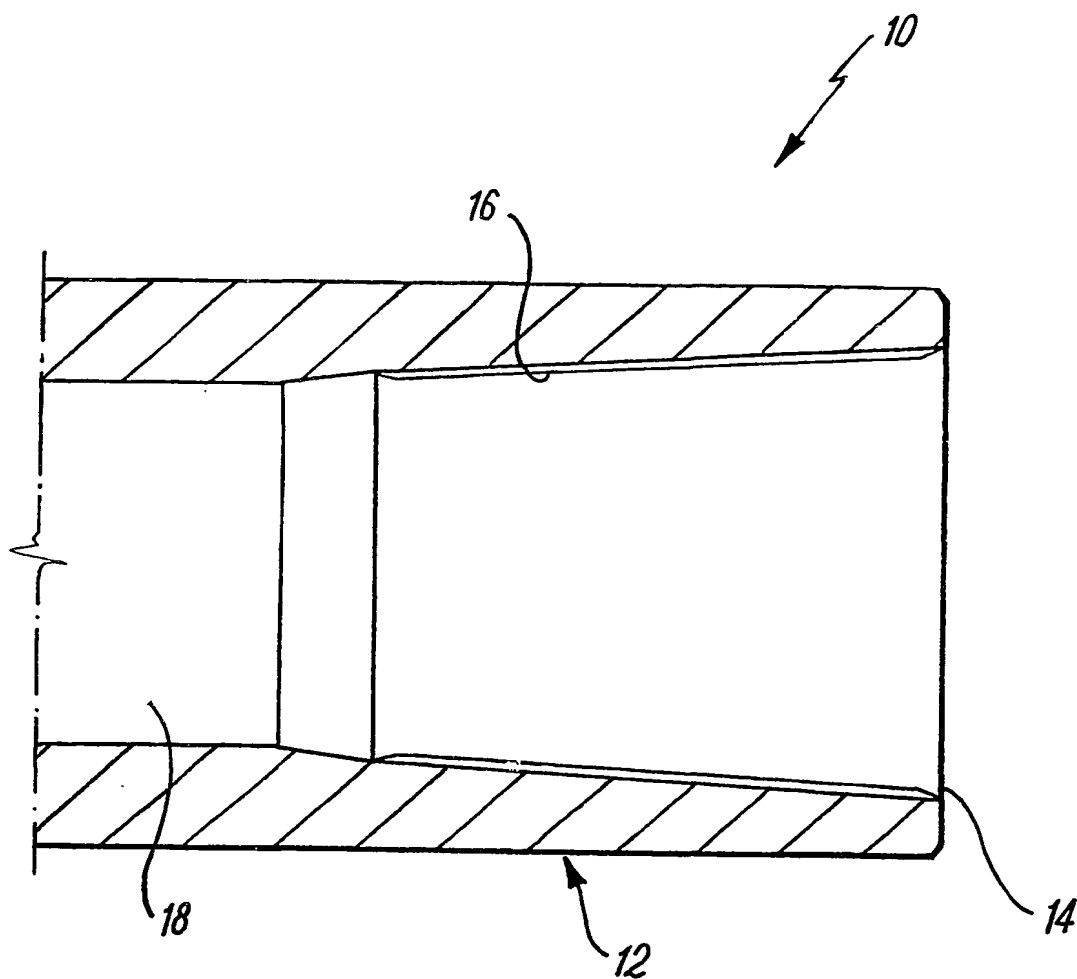
27

28 (d) by increased fluid pressure, moving the first  
29 ball in the through passage, the movement of  
30 the first ball causing a pressure differential  
31 sufficient to move a member, closing the radial  
32 port and releasing the second ball into the  
33 through passage.

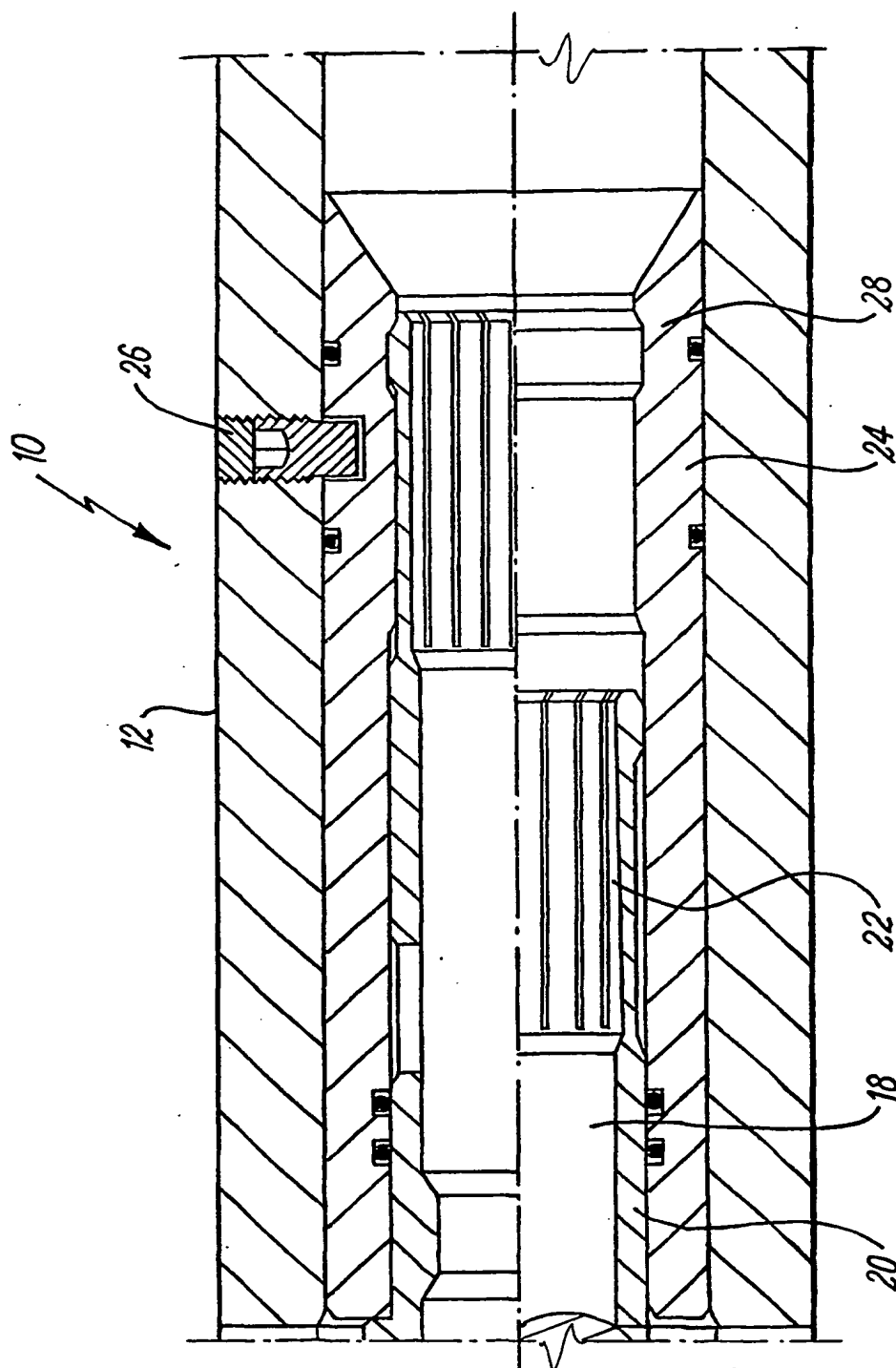
- 1        14. A method of circulating fluid in a borehole  
2        comprising the steps of:  
3  
4        (a) connecting a down hole tool, according to any  
5        one of Claims 9 to 12, in a drill string  
6        suspended in the borehole;  
7  
8        (b) establishing fluid flow through the axial  
9        through passage of the tool;  
10  
11       (c) releasing the first ball means into the axial  
12       through passage to seat in the upper ball  
13       retaining means thereby obstructing the axial  
14       fluid flow through the tool;  
15  
16       (d) moving the obturating member by the increase of  
17       fluid pressure against the first ball means to  
18       locate the radial port with the second outlet  
19       thereby allowing fluid flow through the second  
20       outlet;  
21  
22       (e) releasing the second ball means from the  
23       surface, such that the second ball means  
24       locates in the radial port thereby obstructing  
25       the fluid flow through the second outlet;  
26  
27       (f) forcing the first ball means passed the upper  
28       ball retaining means by the increase in  
29       pressure so as to locate the first ball means  
30       in the lower ball retaining means, the first  
31       ball means falling a distance comparatively  
32       short enough to ensure sufficient pressure to  
33       move the obturating member back up the tubular



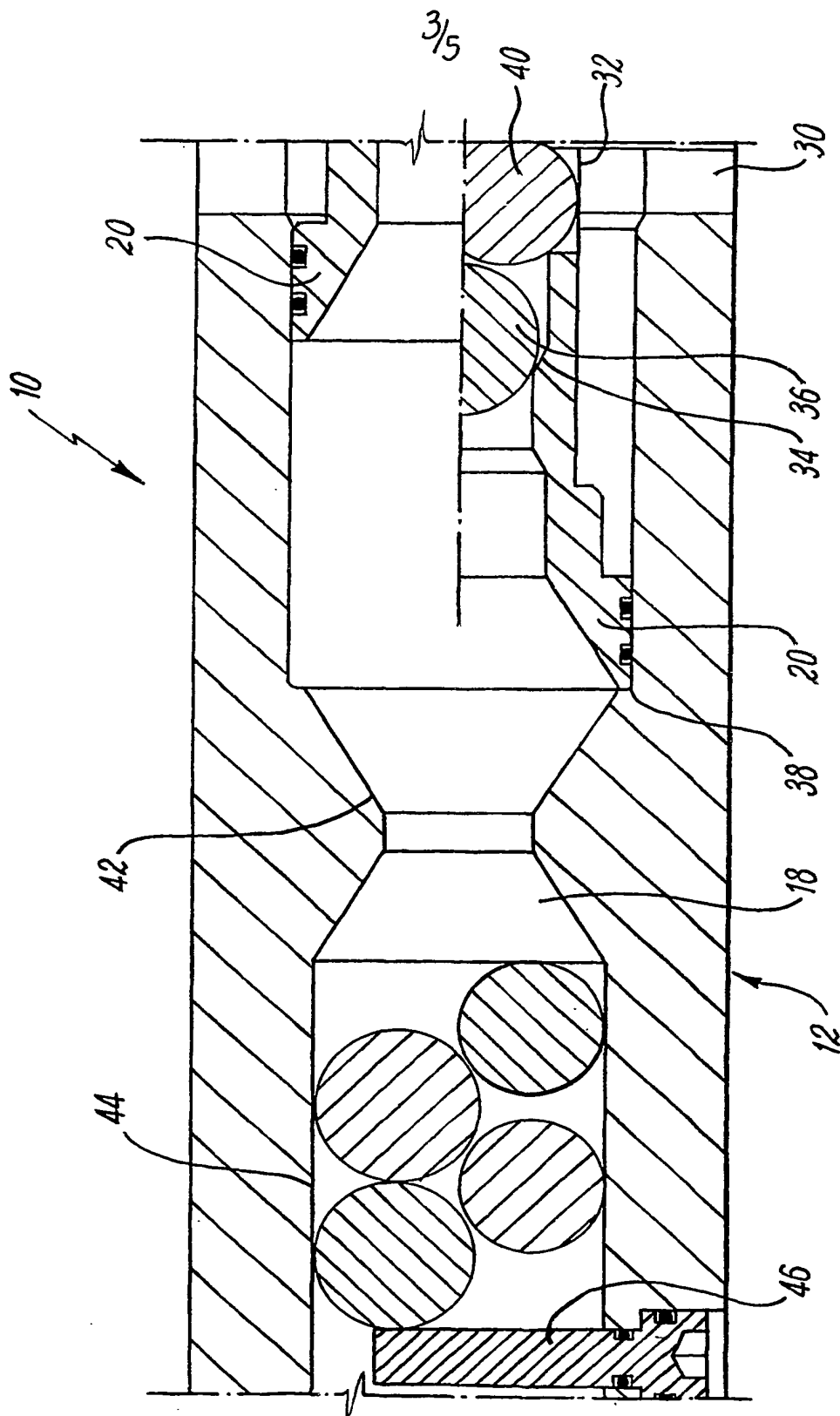
- 1 assembly thereby closing the radial port and  
2 releasing the second ball means; and  
3  
4 (g) allowing the fluid pressure to increase to a  
5 sufficient pressure to cause the first ball  
6 means to pass through the lower ball retaining  
7 means and the second ball means to follow  
8 therethrough and allow axial fluid flow to be  
9 re-established.  
10
- 11 15. A method of circulating fluid in a borehole as  
12 claimed in Claim 13 or 14 including the step of  
13 catching the ball means in a catching means at the  
14 bottom of the tool.  
15
- 16 16. A method of circulating fluid in a borehole as  
17 claimed in any of Claims 13 to 15 wherein the steps  
18 are repeated to provide selected circulation of  
19 fluid when the tool is in the borehole.

$\frac{1}{5}$ **FIG. 1**

2/5

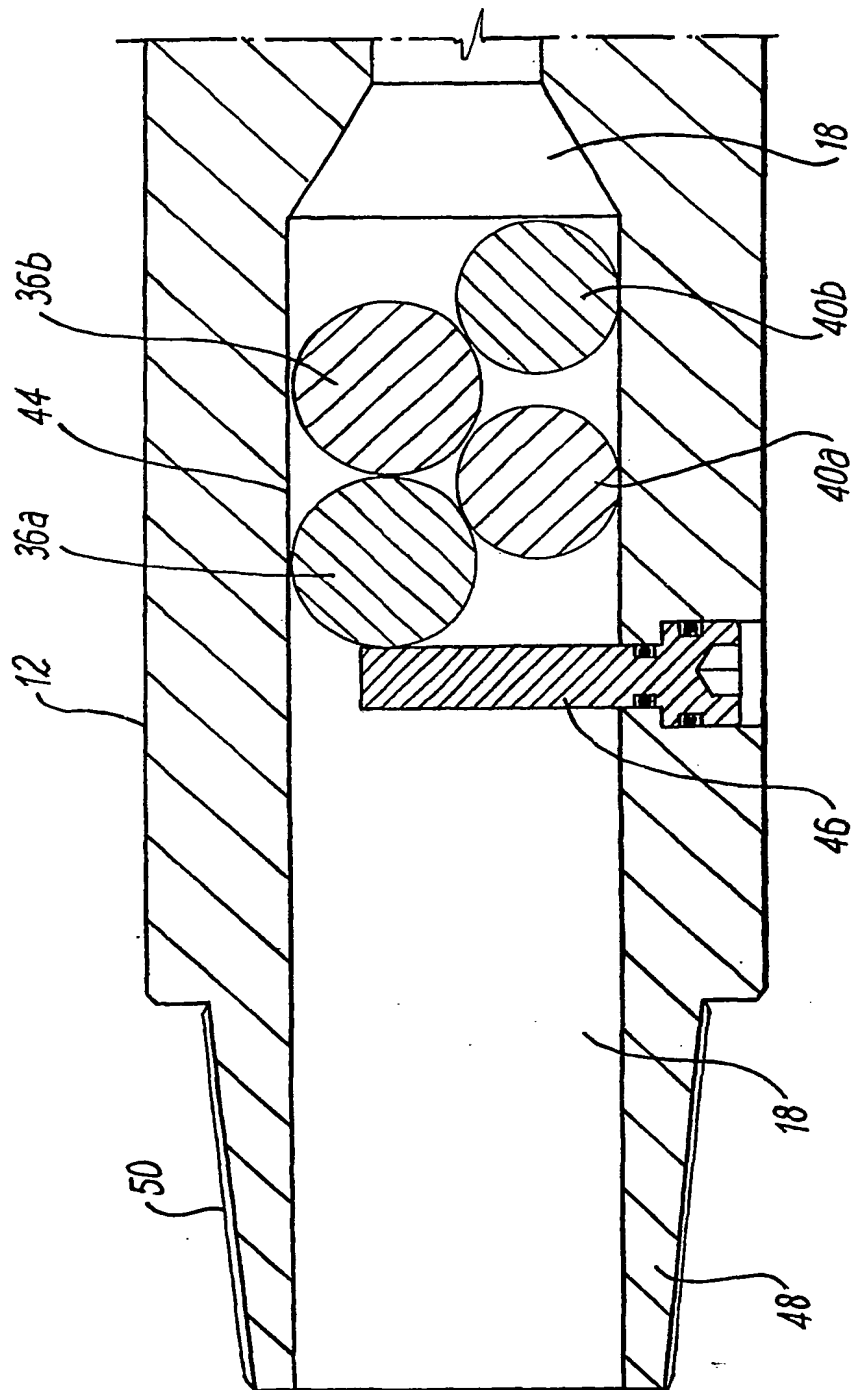


**Fig. 2**

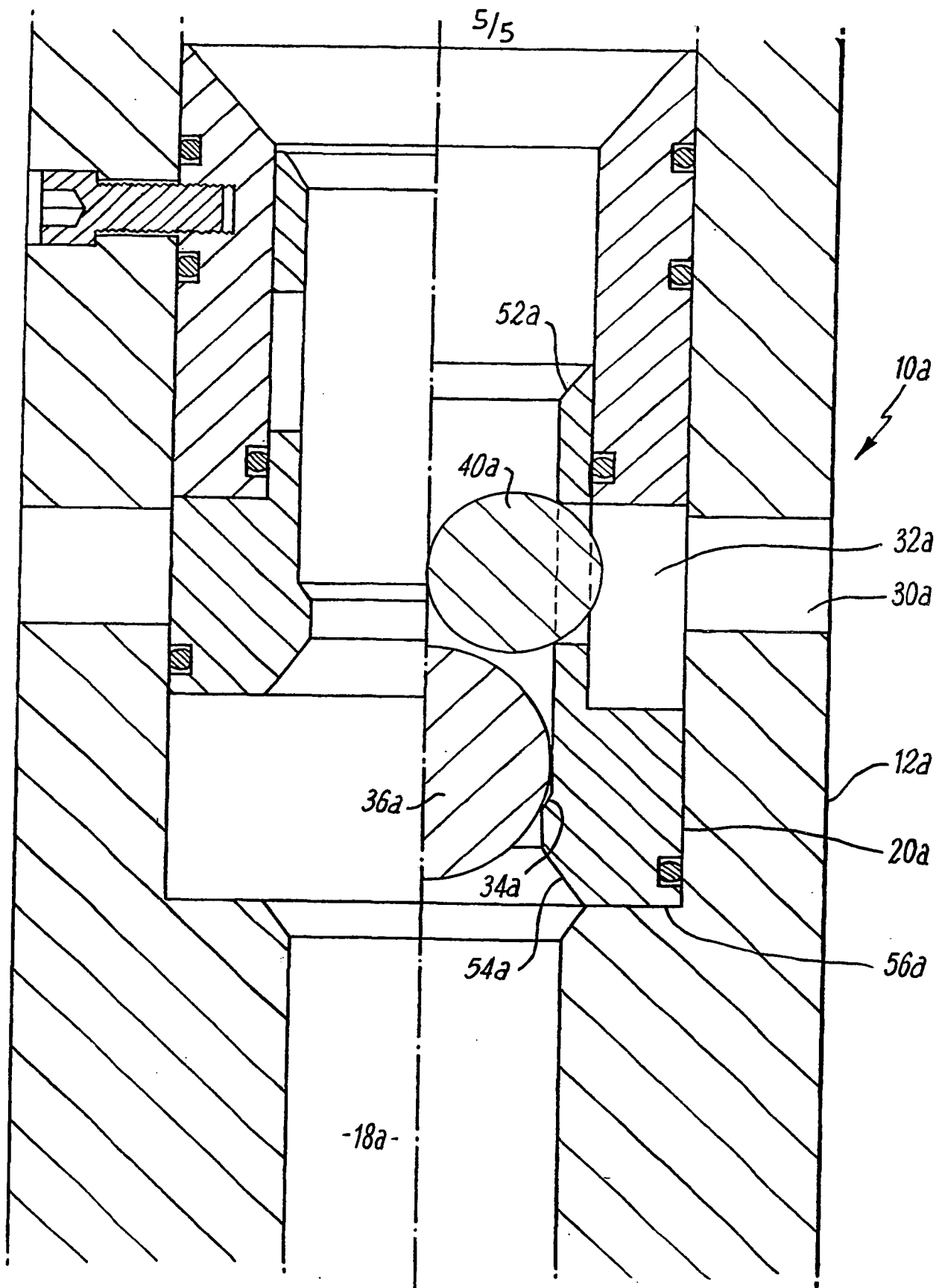


**Fig. 3**

4/5



**Fig. 4**



***FIG. 5***

SUBSTITUTE SHEET (RULE 26)

# INTERNATIONAL SEARCH REPORT

1st Application No  
PCT/GB 02/00083

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 E21B21/10 E21B34/14

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)  
EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 499 687 A (LEE PAUL B) 19 March 1996 (1996-03-19)	13, 15, 16
Y	claims 1-4; figures 1-5 ---	1-9, 14
Y	GB 2 341 405 A (SPECIALISED PETROLEUM SERV LTD) 15 March 2000 (2000-03-15) figures 1-6 ---	1-9, 14
P, X	WO 01 90529 A (LEE PAUL BERNARD) 29 November 2001 (2001-11-29) page 6, paragraph 1 -page 7, paragraph 3; figures 1-3 ---	13, 15
A	US 5 533 571 A (SURJAATMADJA JIM B ET AL) 9 July 1996 (1996-07-09) column 5, line 57 -column 6, line 41; figures 1-4 --- -/--	1

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

30 May 2002

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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